

Recent BES measurements and the hadronic contribution to the QED vacuum polarization

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We have updated our evaluation of the hadronic contribution to the running of the QED fine structure constant using the recent precise measurements of the e^+e^- annihilation at the center-of-mass (c.m.s.) energy region between 2.6 and 3.65 GeV performed by the BES collaboration. In the low energy region, around the ρ resonance, we include the recent measurements from the BABAR, CDM-2, KLOE and SND collaborations. We obtain $\Delta\alpha_{\text{had}}^{(5)}(s) = 0.02750 \pm 0.00033$ at $s = m_Z^2$.

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We have been following up on the cross section measurements of e^+e^- annihilation into hadrons for many years, and provide up-to-date evaluations of the hadronic contribution to the running of the QED fine structure constant $\Delta\alpha_{\text{had}}^{(5)}(s)$ at $s = m_Z^2$, based on a dispersion integration which uses the experimental data as input [1][2][3].

The measured hadronic cross sections are conveniently given as R_{had} , i.e. in units of the QED cross-section for lepton-pair production.

The BES collaboration has previously measured the R_{had} value for e^+e^- annihilation in the c.m.s. energy range between 2 and 5 GeV [4][5] (BES1999, BES2001 in Fig. 1). This energy region is particularly important for the analysis of $\Delta\alpha_{\text{had}}^{(5)}(s)$ [2]. These results were presented at the ICHEP 2000 Conference in Osaka [6] and were included in the evaluation of $\Delta\alpha_{\text{had}}^{(5)}(s)$ [2]. This had a significant impact on the LEP ElectroWeak Group Standard Model precision measurement fits: the most probable value of the Higgs mass moved up from 60 GeV to 88 GeV [7] giving a more coherent picture of the Standard Model of particle physics. The large number of points measured by the BES collaboration, allows to connect and integrate these directly, taking into account the correlation between the systematic uncertainties and uncorrelated statistical errors. As a result, the dispersion integral in the 2 to 5 GeV range was obtained with a precision of 5.9%.

More recently, the BES collaboration has published [8] (referred to as BES2009) measurements of R_{had} at 2.60, 3.07 and 3.65 GeV with statistical errors below the 1% level, and systematic errors of about 3.5%. In order to properly include these new measurements in our analysis, we have divided the BES1999 and BES2001 data points

into three c.m.s. energy regions: the region covered by the recent BES2009 measurements to which we refer to as the overlap region, and the regions below and above. We evaluate the dispersion integral based on the earlier data separately in these three regions, assuming conservatively that the systematic errors in these three regions are fully correlated. The recent BES2009 data gives us an additional, more precise result for the dispersion integral in the overlap region. This result is combined with the previous results assuming a conservative value of 0.5 for the correlation between the systematic uncertainties in the previous and recent BES data. We obtain the total uncertainty of the dispersion integral in the three regions of 7.6% ("below"), 3.7% ("overlap") and 5.0% ("above"). As a result of the inclusion of the recent BES data, the value of the dispersion integration in the c.m.s. energy region from 2 to 5 GeV decreases from 0.00381 to 0.00371 and the overall uncertainty from 5.9% to 5.0%.

At very low energies around the ρ , we used in our previous publication [3], the results from the CMD-2 collaboration with cross section measurements in the c.m.s. energy region between 0.61 and 0.96 GeV [9] (CMD-2 2004) and the KLOE collaboration pion form factor data using the "radiative return" from the ϕ resonance to the ρ in the $\pi^+\pi^-$ mass range between 0.59 and 0.97 GeV [10]. The small ρ contribution from lower and higher energies, not covered by data, was evaluated using the CMD-2 parametrization of the pion form factor [9].

In the low energy region, around the ρ resonance, we now include in our analysis all recent measurements from the BABAR, CDM-2, KLOE and SND collaborations. The KLOE collaboration has superseded the previous measurements by new ones [11] (KLOE2008) in the same c.m.s. energy region. In addition a new analysis [12] (KLOE2010), in which the "radiative return" photon was detected in the detector, has allowed the collaboration to extend the $\pi^+\pi^-$ mass range down to the threshold for the di-pion production. The CMD-2 [13] (CMD-2 2007) and SND collaborations [14] (SND 2005) at Novosibirsk

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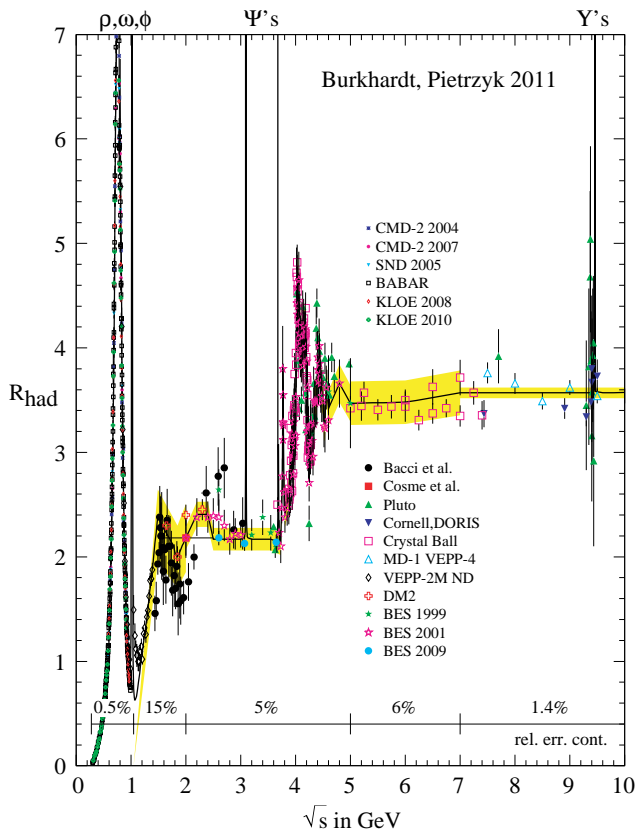


FIG. 1: R_{had} including resonances. Measurements are shown with statistical errors. The relative uncertainty assigned to our parametrization is shown as band and given with numbers at the bottom.

have published new measurements in the c.m.s. energy region between 0.6 and 0.97 GeV and between 0.39 and 0.97 GeV, respectively. Finally, the BABAR collaboration [15] has used the "radiative return" measurements from the c.m.s. energies near 10.6 GeV to measure the $\pi^+\pi^-$ cross section from threshold up to a c.m.s. energy of 3 GeV.

The contribution of the new results on $\Delta\alpha_{\text{had}}^{(5)}(m_Z^2)$ was obtained by direct integration between measured data points and the small ρ contribution from lower and higher energies, not covered by data, was evaluated using the CMD-2 parametrization of the pion form factor [9] as in our previous analysis [3]. We found excellent agreement between the dispersion integral results of all these measurements. We have combined them assuming

full correlation between systematic uncertainties in the same experiment, CMD-2 and KLOE, and no correlation between different experiments. The value of the ρ dispersion integration has increased from 0.00347 in [3] to 0.00349 and the relative uncertainty has decreased from 0.9% to 0.5%.

Fig. 1 and Table I give the summary of R_{had} measurements by different experiments and the current precision in different e^+e^- c.m.s. energy regions.

TABLE I: Contributions to $\Delta\alpha_{\text{had}}^{(5)}(m_Z^2)$

Range \sqrt{s} , GeV	$\Delta\alpha$	Relative error
ρ	0.00349	0.5 %
Narrow resonances	0.00184	3.1 %
1.05 – 2.0	0.00156	15 %
2.0 – 5.0	0.00371	5.0 %
5 – 7	0.00183	6 %
7 – 12	0.00304	1.4 %
> 12	0.01203	0.2 %
	0.02750	1.2 %

We obtain a value of the hadronic contribution to the running of the QED fine structure constant of $\Delta\alpha_{\text{had}}^{(5)}(s) = 0.02750 \pm 0.00033$ at $s = m_Z^2$ corresponding to $1/\alpha^{(5)}(m_Z^2) = 128.951 \pm 0.045$. Similar values for $\Delta\alpha_{\text{had}}^{(5)}(m_Z^2)$ have recently been obtained by M. Davier et al. of 0.02749 ± 0.00010 [16] and by the HLMNT group [17] of 0.02760 ± 0.00015 . The uncertainty quoted by us for the running of the fine structure constant is directly obtained from the experimental uncertainties. The uncertainties obtained in Refs. [16] and [17] are reduced by relying on perturbative QCD to calculate R_{had} in various regions, including the region of the recent measurements of the BES collaboration.

A simple parametrization of the hadronic contribution to the vacuum polarization as a function of energy [18, 19] is used in many computer programs. This parametrization provides a description of the dispersion integral result within 0.2σ in the whole t -channel and the exact value at m_Z in the s -channel. The computer code for $\Delta\alpha_{\text{had}}^{(5)}(s)$ with this parametrization is available from the authors.

Our new value of $\Delta\alpha_{\text{had}}^{(5)}(m_Z^2) = 0.02750 \pm 0.00033$ increases the preferred Higgs mass value from 89_{-26}^{+35} to 93_{-27}^{+35} GeV and the one-sided 95% confidence level upper limit from 158 to 163 GeV [20].

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